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Attorney Docket No: R 36311

Method for Operating an Internal Combustion EngineState of the Art

5 The invention relates to a method and an arrangement for  
operating an internal combustion engine, especially of a motor  
vehicle, wherein fuel is directed into the combustion chamber and  
there combusted.

10 The operation of internal combustion engines in the presence  
of unfavorable operating conditions can lead to the formation of  
deposits in the combustion chamber. Especially for engines  
having direct fuel injection, deposits can form, for example, on  
the injection valves, that is, on the tips or in the tips of the  
injection valves. These deposits can operate unfavorably on the  
spray preparation and therefore on the combustion. As a rule,  
15 one speaks of a coking of the injection valves.

An electronic control arrangement is known from  
DE 198 28 279 A1 by means of which an equalization of the  
cylinder-individual torque contributions can be carried out in a  
multi-cylinder engine. Here, to balance the cylinder-individual  
torque contributions, the injected fuel quantity, the ignition  
20 time point (for a spark-ignition engine), the exhaust gas  
recirculation rate or the injection position are varied. The  
determination of the cylinder-individual torque contributions can  
take place via the evaluation of the time-dependent trace of the  
rotational movement of the crankshaft or camshaft and wherein  
25 individual segment times are detected. Alternatively, rough  
running values can be used which are anyway formed in the control  
apparatus for the detection of combustion misfires. The aim of  
the cylinder equalization is to minimize the rough running values  
30 with a control concept. Corresponding interventions can be

undertaken on the engine in dependence upon the detected pattern and from the magnitude of the individual filtered and unfiltered rough running values. A coking of injection valves can cause a torque of the corresponding cylinder which is too low especially in an engine having direct injection. In this case, the corresponding cylinder runs too lean. The main components for the control function are cylinder-individual PI controllers in correspondence to DE 198 28 279 A1.

The not-yet published German patent application DE 100 09 065.6 describes a method and an arrangement for monitoring the effects of a cylinder equalization control. Corresponding to the introduction of the description, it is a special requirement for a direct-injecting spark-ignition engine. Here, an increased rough running can occur caused by a low tolerance compatibility of the combustion process in stratified operation and/or because of tolerances of the high pressure injection valves which are used or in the distribution of the fuel to the individual cylinders. Also, deterioration-caused changes of the throughflow characteristics of the high pressure injection valves can have an effect. In the context of DE 100 09 065.6, preferably the torque contribution (actual torque) of a cylinder relative to its ignition predecessor is detected (that is, no absolute torque determination) via an evaluation of the time-dependent trace of the crankshaft rotation or camshaft rotation. Improvements in the area of cylinder equalization are achieved in that a monitoring of the effects for the cylinder equalization control is provided and in that a corresponding fault signal is generated for disturbances in the area of the cylinder equalization control. The monitoring of the effects takes place in such a manner that the cylinder-individual

torque contributions can be checked after a completed cylinder equalization control intervention to determine if the control shows an effect. If the effect does not occur to the extent as wanted, the control loop amplification of the cylinder-individual  
5 PI controllers is successively reduced to a pregiven end value. The control thereby functions with greater robustness but is dynamically slower which is accepted. If the wanted effect does not occur after adjusting the PI controllers to the pregiven end value, then a fault signal is generated.

10 The disclosure of the last-mentioned German patent application DE 100 09 065.6 is expressly incorporated into this application.

The present invention has as its object to provide a method of the above kind with which depositions in the combustion  
15 chambers of the engine can be detected and removed in a simple manner.

The task of the present invention is solved with the features of claim 1.

#### Advantages of the Invention

20 The especially great advantage of the present invention is that the combustion chamber can be kept free of deposits with simple means over the entire service life of the engine, whereby always optimal conditions are given for a good combustion.

A further advantage of the invention is that the combustion  
25 temperature is reduced with the injection of water and, associated therewith, the NOx emission becomes lower. Furthermore, the thermodynamic efficiency of the engine is improved because of the water vapor pressure of the water vaporized in the combustion chamber at high temperature.

30 Further advantages of the invention are evident in

combination with the dependent claims from the description of the embodiments which follows.

#### Drawing

Embodiments of the invention are shown in the drawing and  
5 are explained in greater detail in the following description.

FIG. 1 schematically shows an internal combustion engine having a control apparatus;

FIG. 2 shows a flowchart of the method of the invention;  
and,

10 FIG. 3 schematically shows an internal combustion engine having a control apparatus and having a device with which water or any other desired cleaning liquid can be added to the inducted combustion air.

#### Description of the Embodiments

15 In FIG. 1, an internal combustion engine 1 is shown wherein a piston 2 is movable back and forth in a cylinder 3. The cylinder 3 is provided with a combustion chamber 4 to which an intake manifold 6 and an exhaust-gas pipe 7 are connected via valves 5. Furthermore, an injection valve 8 and a spark plug 9  
20 are associated with the combustion chamber 4. The injection valve 8 is driven by a signal TI and the spark plug 9 is driven by a signal ZW. The signals TI and ZW are transmitted by a control apparatus 16 to the injection valve 8 and the spark plug 9, respectively.

25 The intake manifold 6 is provided with an air mass sensor 10 and the exhaust-gas pipe 7 is provided with a lambda sensor 11. The air mass sensor 10 measures the air mass of the fresh air supplied to the intake manifold 6 and generates a signal LM in dependence thereon. The lambda sensor 11 measures the oxygen  
30 content of the exhaust gas in the exhaust-gas pipe 7 and

generates a signal  $\lambda$  in dependence thereon. The signals of the air mass sensor 10 and of the  $\lambda$  sensor 11 are supplied to the control apparatus 16.

5 A throttle flap 12 is accommodated in the intake manifold 6 and the rotational position of the throttle flap is adjusted by means of a signal DK.

10 In a first mode of operation, the stratified operation of the engine 1, the throttle flap 12 is opened wide. The fuel is injected into the combustion chamber 4 by the injection valve 8 during a compression phase caused by the piston 2. Then, the fuel is ignited with the aid of the spark plug 9 so that the piston 2 is driven in the next work phase by the expansion of the ignited fuel.

15 In a second operating mode, the homogeneous operation of the engine 1, the throttle flap 12 is partially opened or closed in dependence upon the desired supplied air mass. The fuel is injected into the combustion chamber 4 by the injection valve 8 during an induction phase caused by piston 2. Because of the simultaneously inducted air, the injected fuel is swirled and it is thereby essentially uniformly distributed in the combustion chamber 4. Thereafter, the air/fuel mixture is compressed during the compression phase in order to then be ignited by the spark plug 9. The piston 2 is driven with the expansion of the ignited fuel.

25 In the stratified operation as well as in the homogeneous operation, a rotational movement is imparted by the driven piston to a crankshaft 14 via which the wheels of the motor vehicle are driven. A toothed wheel 16 is mounted on the crankshaft 14 and the teeth thereof are scanned by an rpm sensor 15 mounted directly opposite. The rpm sensor 15 generates a signal from

30

which the rpm N of the crankshaft 14 is determined and the sensor transmits this signal to the control apparatus 16.

The fuel mass, which is injected into the combustion chamber by the injection valve 8 in stratified operation and in  
5 homogeneous operation, is controlled (open loop and/or closed loop) by the control apparatus 16 especially with the view to a low consumption of fuel and/or a low development of toxic substances. For this purpose, the control apparatus 16 is provided with a microprocessor which has a program stored in a  
10 storage medium, especially in a read-only-memory (ROM), which program is suited to carry out the entire control (open loop and/or closed loop) of the engine 1.

Input signals are applied to the control apparatus 16 and represent operating variables of the engine which are measured by  
15 means of sensors. For example, the control apparatus 16 is connected to the air mass sensor 10, the lambda sensor 11 and the rpm sensor 15. Furthermore, the control apparatus 16 is connected to an accelerator pedal sensor 17 which generates a signal FP, which indicates the position of an accelerator pedal  
20 actuated by the driver and therefore the torque commanded by the driver. The control apparatus 16 generates output signals with which the performance of the engine 1 can be influenced in correspondence to the desired control (open loop and/or closed loop) via actuators. For example, the control apparatus 16 is  
25 connected to the injection valve 8, the spark plug 9 and the throttle flap 12 and generates the signals TI, ZW and DK, which are needed to drive the foregoing.

FIG. 2 shows a flowchart of the method of the invention especially for an internal combustion engine having  
30 gasoline-direct injection.

Step 215 is described in FIG. 2. In this step, an inquiry is made as to the effect of the cylinder equalization control and is based, for example, on the method for monitoring the effects of a cylinder equalization control described in the non-published German patent application DE 100 09 065.6. The input data needed herefor are supplied by the rpm sensor 15 to the control apparatus 16, which, on this basis, undertakes the control/adaptation of the cylinder-individual torque contributions. For this purpose, for example, the injected fuel quantity TI, the ignition time point ZW, the exhaust-gas recirculation rate (not shown in FIG. 2) or the injection position TI is varied by the control apparatus 16.

After a start of the method, a check is made in step 210 as to whether stratified operation is present. As long as no stratified operation is given, this inquiry is carried out continuously. If, in contrast, stratified operation is present, then a check is made in step 215 as to whether a fault signal of the monitoring of effects is present. If this is the case (that is, the cylinder equalization shows no effect), a transition is made directly to step 250, which is described in detail hereinafter. Accordingly, a conclusion is directly drawn as to coking. If, in contrast, it is established in step 215 that the monitoring of the effects of the cylinder equalization generates no fault signal, then a check is made in step 220 as to whether combustion misfires occur in the operating mode "stratified operation". If no combustion misfires can be determined, then there is a return to step 210. If, in contrast, combustion misfires are detected, then, there is a switchover in step 230 from the operating mode "stratified operation" into the operating mode "homogeneous operation" with the aid of the control

apparatus 16.

In step 240, as already in step 220, a check is made in the operating mode "homogeneous operation" as to whether combustion misfires occur. If no combustion misfires are determined, then a conclusion is drawn therefrom in step 250 that the injection valves are coked, that is, deposits have formed on the injection valves.

Deposits on the injection valves can lead to the spray preparation being disturbed in the direct injection of gasoline. Approximately the same fuel quantity is injected into the combustion chamber 4 but the spray form or the spray guidance is changed because of the deposits. This has negative effects especially in stratified operation because, at the ignition time point, no ignitable air/fuel cloud is present in the direct vicinity of the spark plug 9 whereby combustion misfires occur or even no combustion takes place. In the homogeneous operation, a slight coking of the injection valves disturbs little because here the combustion is not essentially dependent upon the spray guidance of the injected fuel. The fuel is injected early, namely, already during the induction phase, whereby sufficient time is present for a uniform distribution.

In step 260, measures are initiated in order to remove the deposits on the injection valves 8. Alternatively to ending the method shown in FIG. 2, a jump back to step 210 can take place after step 260 in order to check whether the measures for combustion chamber cleaning were successful. This alternative is indicated by a broken line.

A knocking combustion can be used as a measure for removing deposits. Investigations on internal combustion engines, which were operated with knocking combustion, show that these engines

have very clean combustion chambers. This effect is utilized in this invention.

This can be attributed to pressure fluctuations which are generated by the knocking combustion, with these pressure  
5 fluctuations being superposed on the normal pressure trace. With the additional pressure fluctuations, intense high frequency vibrations are generated whereby the deposits in the combustion chamber 4 and especially on the nozzles of the injection valves 8  
can be removed. The knocking combustion must be limited in time  
10 in order to avoid damage to the engine 1.

Also, water or any desired other cleaning liquid can be added to the inducted combustion air in combination with the knocking combustion or even as an independent method whereby a similar cleaning effect can be achieved as with the knocking  
15 combustion. Investigations of engines wherein water has penetrated into the combustion chamber 4 (via a non-tight cylinder head seal or injected additionally) have shown that these engines always have especially clean combustion chambers.  
This effect is used in this invention.

20 After the combustion cleaning has been carried out, a switchover to stratified operation again takes place in order to check whether the engine 1 runs without misfires. If misfires are again determined, the method can again be started anew.

As a precaution or to avoid the occurrence of deposits in  
25 the combustion chamber, a knocking combustion can be carried out and/or water can be added to the air at specific time intervals.

If combustion misfires were detected in step 240 also in homogeneous operation, then, in step 270, a further diagnostic method is started. The combustion misfires, in this case, cannot  
30 be caused exclusively by deposits on the nozzles of the injection

valves. For example, these combustion misfires can also be caused by an injection valve 8, which no longer opens in a controlled manner or by a defective spark plug 9. A coking of the injection valves 9 can, in this case, not be completely precluded. In any case, the reasons for these combustion misfires must be narrowed by further diagnostic methods. A corresponding storage of the faults in a fault memory can be helpful in a later repair in order to obtain a precise diagnosis.

FIG. 3 shows an internal combustion engine 1 having a control apparatus 16, as already shown in FIG. 1, and with a device with which water or any desired other cleaning liquid can be added to the air. For the sake of simplicity, the reference numerals of FIG. 1 are taken over for the same components.

A water vessel 18 is additionally mounted on the engine 1. A valve 19 is mounted on the water vessel 18 which can be driven with the aid of the control apparatus 16. The valve 19 is connected to an injection nozzle 20. With the aid of the nozzle 20, water can reach directly into the intake manifold 6 when actuating the valve 19.

If, for example, deposits on the injection valves 8 are detected by the control apparatus 16, a signal WA is generated with which the valve 19 is driven or opened. Because of the underpressure which, as a rule, is present in the intake manifold 6, water is introduced into the intake manifold 6 from the water vessel 18 via the valve 19 and the nozzle 20 when the valve 19 is opened. With the next induction operation of the engine 1, water in the intake manifold 6 reaches the combustion chamber 4. There, the water mixes with the air and fuel reaching the combustion chamber during the injection operation. Because of the high temperature in the combustion chamber 4, the water

vaporizes immediately and contributes to the cleaning of the combustion chamber.

Although an internal combustion engine having gasoline direct injection was selected as an example, it is possible to  
5 apply this method in a somewhat modified form even to other internal combustion engines such as a diesel engine or an internal combustion engine having intake manifold injection.

A special embodiment of the method of the invention is its realization in the form of a computer program having program code  
10 means. Such a computer program can be stored on a storage medium such as a CD-ROM or an EPROM and makes it possible to introduce the method steps of the invention for combustion chamber cleanup when the computer program is executed in a control apparatus (that is, generally in any desired computer). In this way, it  
15 affords the manufacturer of such a product a simple possibility to supply the product to a customer.